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Kroening

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(54) **SYSTEMS AND METHODS FOR USING POWER DIVIDERS FOR IMPROVED FERRITE CIRCULATOR RF POWER HANDLING**

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(51) **Int. Cl.**

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H01P 1/11	(2006.01)
H01P 1/26	(2006.01)
H01P 1/39	(2006.01)
H01P 5/20	(2006.01)
H01P 5/22	(2006.01)

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CPC ***H01P 1/383*** (2013.01); ***H01P 1/11*** (2013.01); ***H01P 1/262*** (2013.01); ***H01P 1/38*** (2013.01); ***H01P 1/39*** (2013.01); *H01P 5/20* (2013.01); *H01P 5/22* (2013.01)

(58) **Field of Classification Search**

CPC H01P 1/32; H01P 1/36; H01P 1/38

USPC 333/1.1, 24.2; 455/78

See application file for complete search history.

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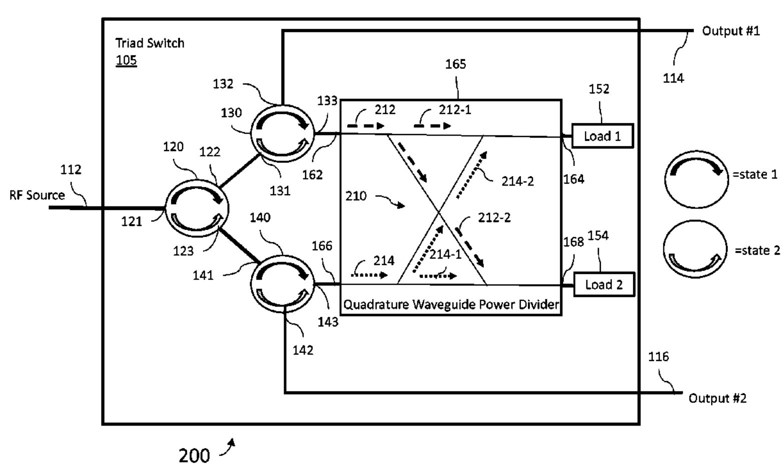
(57) **ABSTRACT**

Systems and methods for using power dividers for improved ferrite circulator RF power handling are provided. In one embodiment, a method for switching RF power using a high power circulator switch comprises: operating a ferrite circulator switch to direct RF power to either a first output port or a second output port, the ferrite circulator switch comprising at least three ferrite circulators arranged as a triad switch, wherein a first circulator is coupled to the first output port, a second circulator is coupled to the second output port; and using a waveguide power divider coupled between the first circulator and the second circulator, distributing reflected RF power received at the first output port or the second output port between a plurality of waveguide loads.

10 Claims, 5 Drawing Sheets



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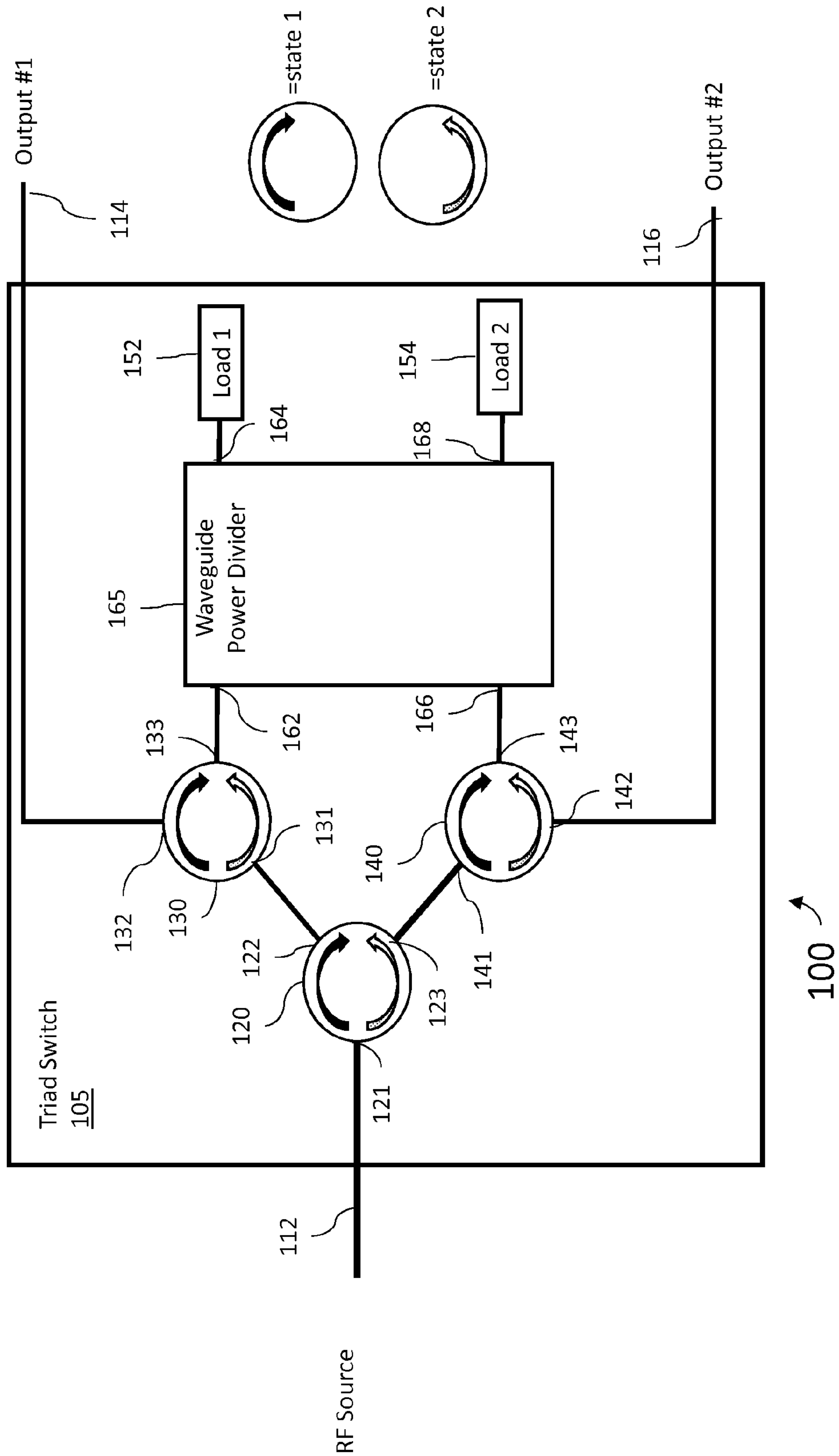
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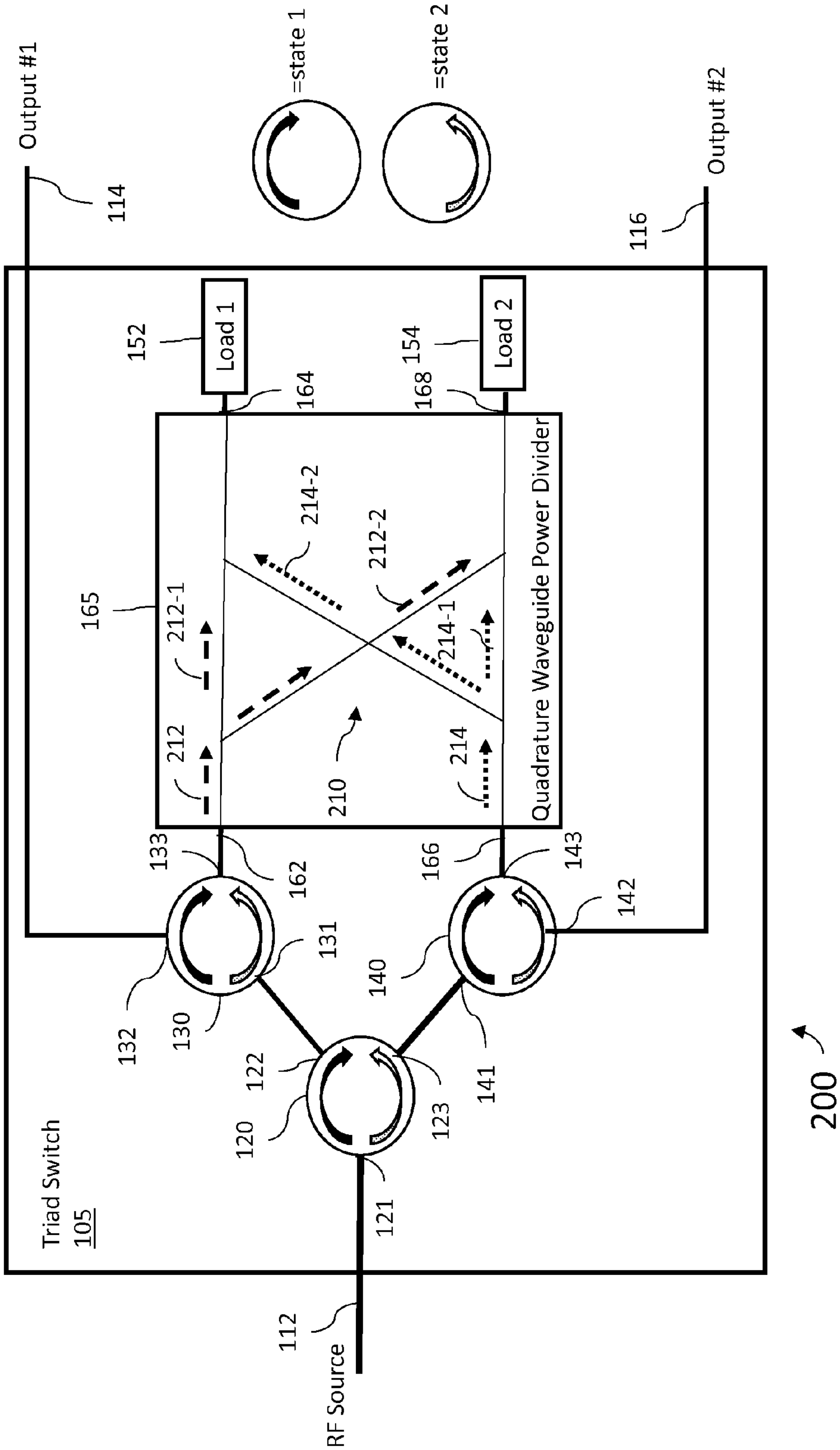
114
=state 1
=state 2
Output #2
116
Triad Switch
105
152
Load 1
154
Load 2
164
168
165
Waveguide
Power Divider
162
166
133
143
131
142
132
130
140
141
122
120
123
121
112
100
RF Source

Fig. 1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114
=state 1
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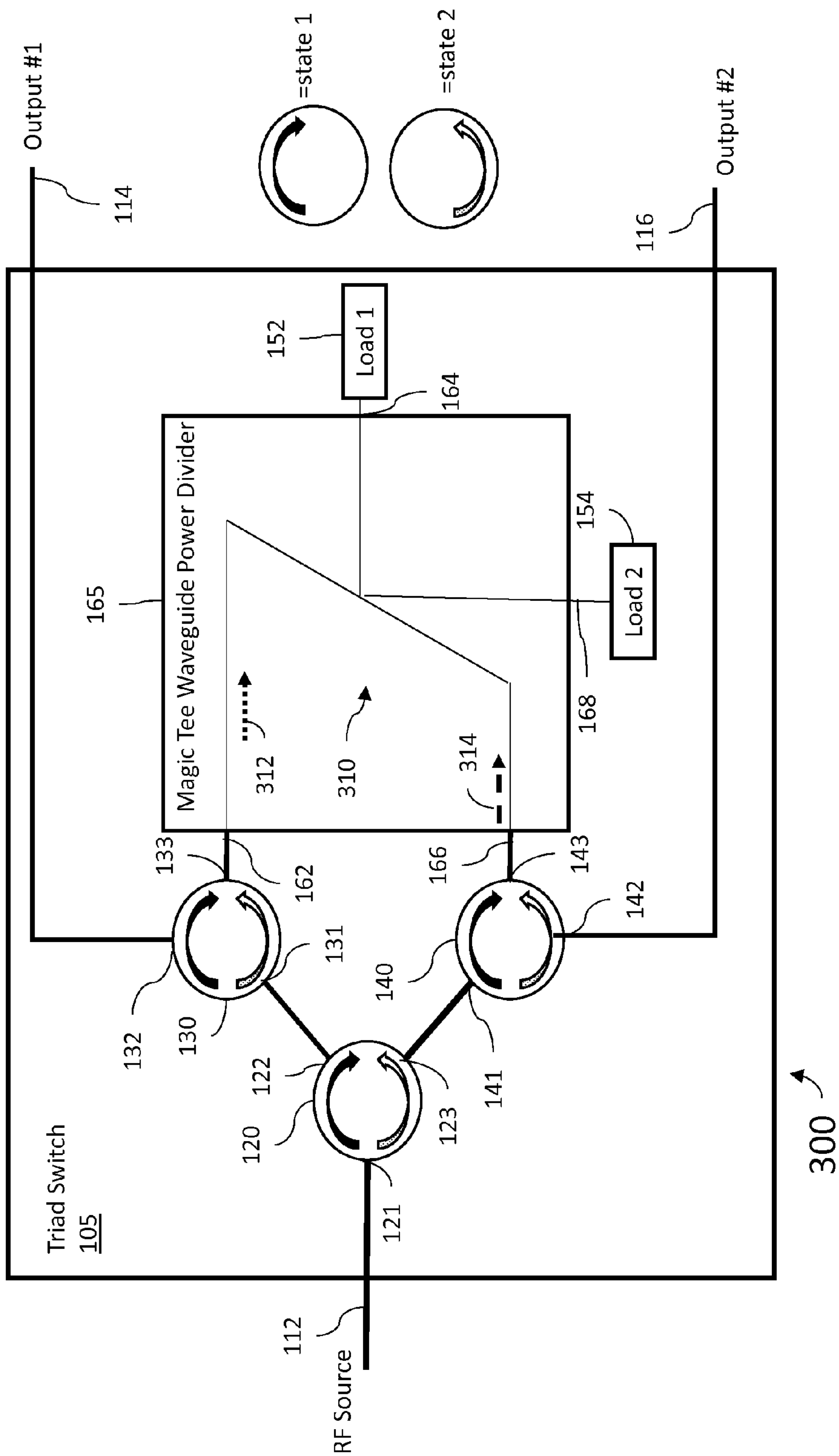
Output #2
116
Load 1
152
Load 2
154
164
168
165
212-1
214-2
212-2
214-1
212
214
210
Quadrature Waveguide Power Divider
133
162
166
143
131
140
142
132
130
122
141
120
123
121
Triad Switch
105
112
RF Source
200

Fig. 2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=state 1
=state 2
Output #2
116
152
Load 1
164
Magic Tee Waveguide Power Divider
154
Load 2
165
168
312
310
314
133
162
166
143
142
131
140
132
130
122
141
120
123
121
Triad Switch
105
300
112
RF Source

Fig. 3

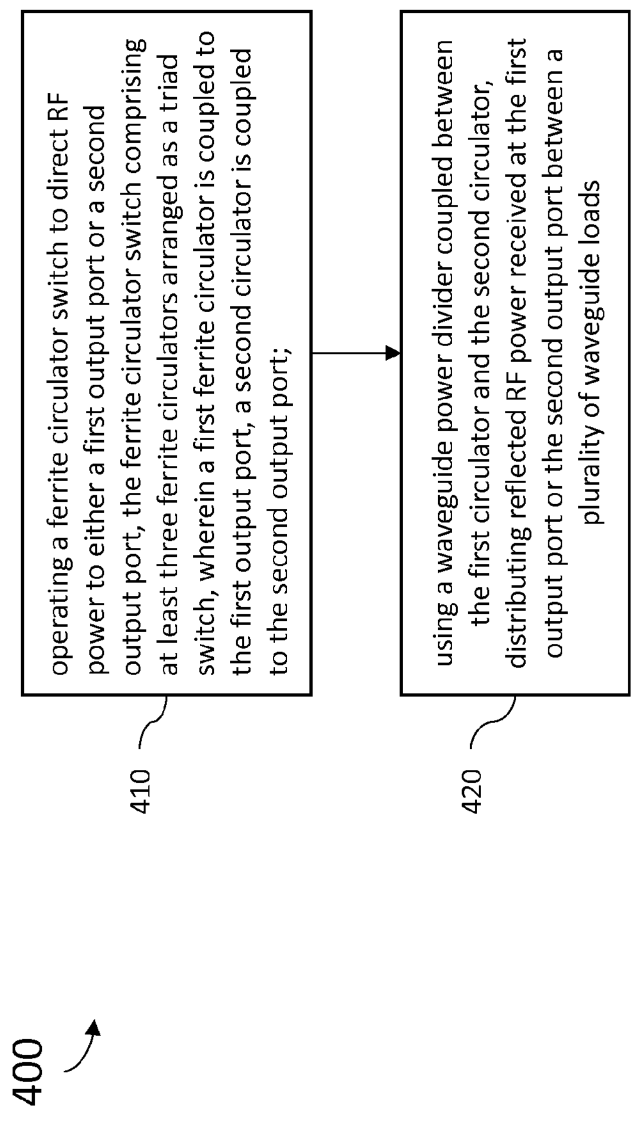
400
410
operating a ferrite circulator switch to direct RF power to either a first output port or a second output port, the ferrite circulator switch comprising at least three ferrite circulators arranged as a triad switch, wherein a first ferrite circulator is coupled to the first output port, a second circulator is coupled to the second output port;
420
using a waveguide power divider coupled between the first circulator and the second circulator, distributing reflected RF power received at the first output port or the second output port between a plurality of waveguide loads

Fig. 4

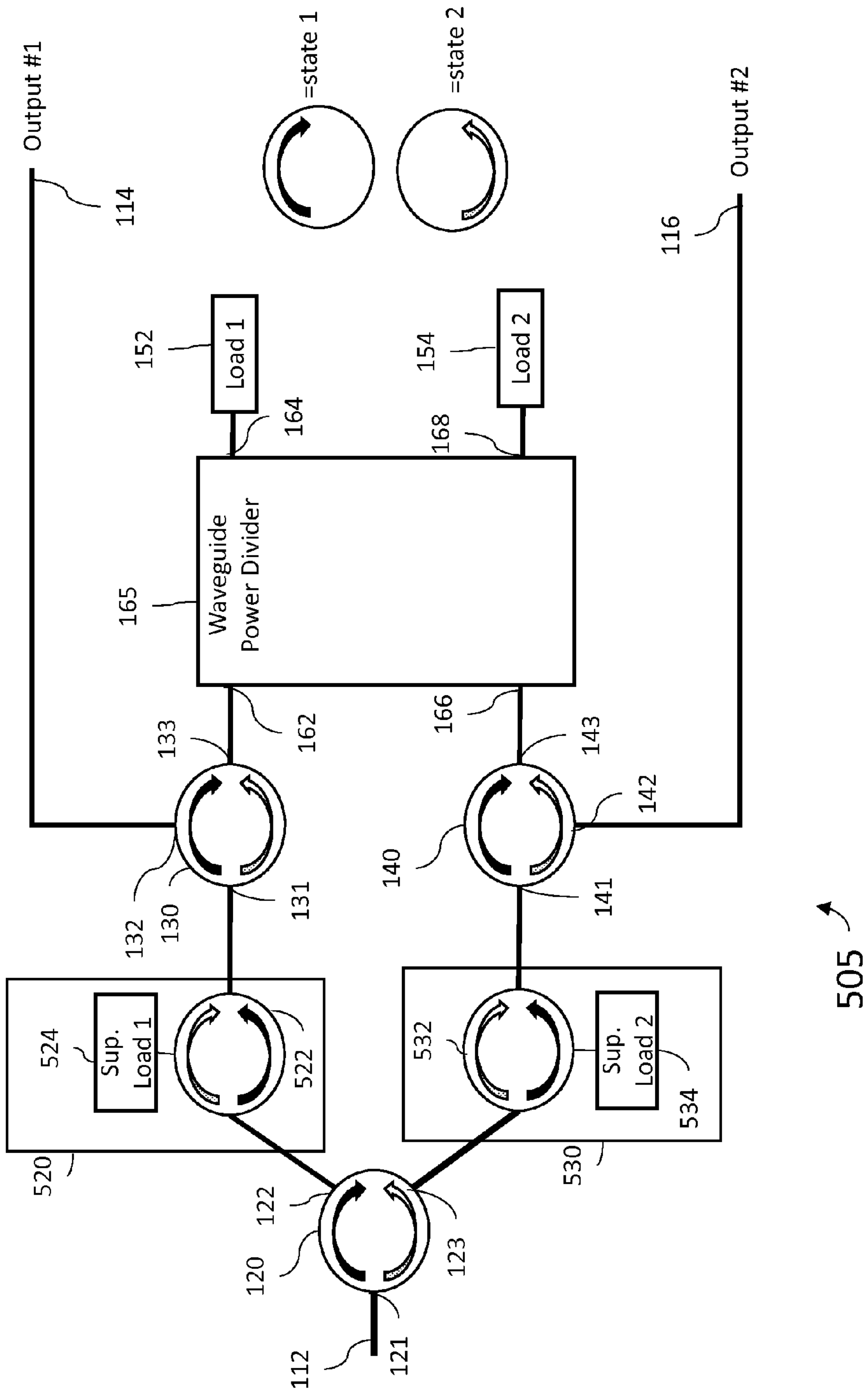
Output #1
=state 1
=state 2
Output #2
114
116
152
Load 1
154
Load 2
164
168
165
Waveguide Power Divider
133
162
166
143
142
140
132
130
131
141
524
Sup. Load 1
522
532
Sup. Load 2
534
520
530
122
120
123
112
121
505

Fig. 5

SYSTEMS AND METHODS FOR USING POWER DIVIDERS FOR IMPROVED FERRITE CIRCULATOR RF POWER HANDLING

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to U.S. patent application Ser. No. 14/247,454 entitled, "SYSTEMS AND METHODS FOR IMPROVED FERRITE CIRCULATOR RF POWER HANDLING", filed on even date herewith, which is incorporated herein by reference in its entirety.

BACKGROUND

Ferrite switching circulators can be used to implement downlink beam hopping techniques in multibeam broadband satellite systems, where a single high power RF input can be quickly switched to multiple output antennas. A single 3-port ferrite circulator switch, although simple to implement, compact and relatively inexpensive, has a downside in that if a short or open circuit occurs within a connected output port, or if an output port is not properly connected, then radio frequency (RF) power can be reflected back into the switch. This reflected power can travel back through the circulator, exit another port of the circulator, and energize equipment that should have remained de-energized. To provide isolation between switched output ports, designs have been introduced comprising a configuration of three multifunction waveguide ferrite circulators (sometimes referred to as a ferrite circulator "triad") which include three ferrite junction switches and two high power loads. In a triad design, one of two high power loads is coupled to a first circulator while the other high power load is coupled to a second circulator. The input to a third ferrite circulator is switched between two outputs, where the first output is coupled to the input of the first ferrite circulator, and the third circulator's second output is coupled to the input of the second circulator. In such a triad design, if a short circuit occurs on a connection to the output port of the first ferrite circulator, then the reflected RF power is reflected back into the circulator and directed to its high power load which serves to absorb the reflected RF power. Similarly, the high power load coupled to the second circulator will receive and absorb reflected RF power received back in from the output port of the second circulator. Since minimal reflected RF power is transmitted back to the third circulator, isolation between the two output ports of the triad is achieved.

In order to improve satellite throughput in satellite communications, specified RF power levels used by satellites have been on the rise. The increases in RF power level may come either through improvements in output power of the on-board high power transmitters or through the combining of several high power transmitters. For this increase in RF power level, the limitation in the triad switches is the power handling of the ferrite switches and high power loads. That is, the high power loads used by the triad switches need to be able to handle the full transmit power levels (which can be on the order of 50 to 500 watts, for example) in case of a short circuit at an output to the switch. The high power loads need to be capable of absorbing the full reflected input power, which typically translates into the need for the high power loads to be larger and heavier. In the design of satellite systems, however, the space available within the satellite is typically a premium resource, and any extra

weight has a direct detrimental effect in the cost associated with launching the satellite into orbit.

For the reasons stated above and for other reasons stated below which will become apparent to those skilled in the art upon reading and understanding the specification, there is a need in the art for improved systems and methods for improved ferrite circulator RF power handling.

SUMMARY

The Embodiments of the present disclosure provide methods and systems for improved ferrite circulator RF power handling and will be understood by reading and studying the following specification.

Systems and methods for using power dividers for improved ferrite circulator RF power handling are provided. In one embodiment, a method for switching RF power using a high power circulator switch comprises: operating a ferrite circulator switch to direct RF power to either a first output port or a second output port, the ferrite circulator switch comprising at least three ferrite circulators arranged as a triad switch, wherein a first circulator is coupled to the first output port, a second circulator is coupled to the second output port; and using a waveguide power divider coupled between the first circulator and the second circulator, distributing reflected RF power received at the first output port or the second output port between a plurality of waveguide loads.

DRAWINGS

Embodiments of the present disclosure can be more easily understood and further advantages and uses thereof more readily apparent, when considered in view of the description of the preferred embodiments and the following figures in which:

FIG. **1** is a block diagram illustrating a triad ferrite circulator switch of one embodiment of the present disclosure;

FIG. **2** is a block diagram illustrating a triad ferrite circulator switch of one embodiment of the present disclosure;

FIG. **3** is a block diagram illustrating a triad ferrite circulator switch of one embodiment of the present disclosure;

FIG. **4** is a flow chart illustrating a method of one embodiment of the present disclosure; and

FIG. **5** is a block diagram illustrating a triad ferrite circulator switch of one embodiment of the present disclosure.

In accordance with common practice, the various described features are not drawn to scale but are drawn to emphasize features relevant to the present disclosure. Reference characters denote like elements throughout figures and text.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of specific illustrative embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that logical, mechanical and electrical changes may be made without departing from the scope of the present disclosure. The following detailed description is, therefore, not to be taken in a limiting sense.

Embodiments of the present disclosure address the needs of triad circulator junction switches to be able to absorb the full reflected input power through new switch designs which incorporate a waveguide power divider to distribute reflected RF energy among multiple waveguide loads. By distributing reflected RF energy to multiple waveguide loads, it is possible to utilize loads having lower power ratings, which are relatively lighter, smaller and less expensive. Further, as explained below, the waveguide power divider is positioned between the output circulators of the triad circulator junction switch so that reflected RF power from both outputs can be applied to the same waveguide power divider, further reducing the total number of waveguide loads necessary to mitigate reflected RF energy.

FIG. **1** is a diagram generally at **100** illustrating a triad ferrite circulator switch **105** (also referred to herein simply as "triad switch" **105**) of one embodiment of the present disclosure. Triad switch **105** includes an input port **112** and two output ports **114** and **116**. Triad switch **105** functions as a switchable waveguide, receiving an RF energy wave at point **112** and switching the wave to either ports **114** or **116**. This switching is achieved while maintaining a high degree of isolation (e.g. >30 dB) between ports **114** and **116**. In the embodiment shown in FIG. **1**, triad switch **105** comprises a triad of ferrite circulators **120**, **130** and **140**. Input port **112** is coupled to an input **121** of a ferrite circulator **120** which is switched between two outputs **122** and **123**. The circulator **120** output **122** is coupled to the input **131** of ferrite circulator **130**, while the circulator **120** output **123** is coupled to the input **141** of ferrite circulator **140**. Port **132** of ferrite circulator **130** serves as the first output port **114** of triad switch **105** while port **142** of ferrite circulator **140** serves as the second output port **116** of triad switch **105**. In this disclosure, the ferrite circulator **130** coupled to first output port **114** may be referred to as the "first circulator **130**", the ferrite circulator **140** coupled to second output port **116** may be referred to as the "second circulator **140**", and the ferrite circulator **120** coupled to the input port **112** may be referred to as the "third circulator **120**."

For the embodiment shown in FIG. **1**, a four port waveguide power divider **165** comprises a first port **162** coupled to port **133** of the first circulator **130** and a second port **166** coupled to port **143** of the second circulator **140**. Port **164** of waveguide power divider **165** is coupled to a first waveguide load **152** while port **168** of waveguide power divider **165** is coupled to a second waveguide load **154**. In operation, in order to dissipate any reflected RF power received back into output ports **114** and **116**, that power is directed to waveguide power divider **165**.

Triad switch **105** has two operating states. In state **1**, port **114** is "on" (i.e. port **114** is coupled to, and receives RF energy from, input port **112**) while port **116** is "off" (i.e., isolated from both the input port **112** and port **114**). In state **2**, port **116** is "on" (i.e. port **116** is coupled to, and receives RF energy from, input port **112**) while port **114** is "off" (i.e., isolated from both the input port **112** and port **116**).

Circulator **120** comprises a ferrite circulator waveguide that includes input port **121**, and first and second output ports **122**, **123**. Depending on the selected state of triad switch **105**, the direction of circulation within circulator **120** is either clockwise (CW) or counter-clockwise (CCW), and an RF energy wave entering input port **121** flows either to port **122** or port **123**. For example, in the embodiment shown in FIG. **1**, when triad switch **105** is in the first state, circulator **120** directs energy through the circulator in a first direction to its first output port **122** and out to the first circulator **130**. When triad switch **105** is in the second state, circulator **120** directs energy through the circulator in a second direction to its second output port **123** and out to the second circulator **140**. Circulators **130** and **140** also each comprises ferrite circulator waveguides, each having input ports **131** and **141**, respectively. Circulator **130** includes an output port **132** that serves as the first output port **114** of triad switch **105**. Circulator **140** includes an output port **142** that serves as the second output port **116** of triad switch **105**.

In one embodiment, this two-state operation is achieved by switching circulator **120** while circulators **130** and **140** are maintained in a fixed state. That is, when circulator **120** is switched to provide an output to circulator **130**, the RF energy is sent to output port **132** and first output port **114** of triad switch **105**. Any reflected RF power received back into port **114** will enter into circulator **130** and travel around the circulator in the first direction to port **162** of waveguide power divider **165**. When circulator **120** is switched to provide an output to circulator **140**, the RF energy is sent to output port **142** and second output port **116** of triad switch **105**. Any reflected RF power received back into port **116** will enter into circulator **140** and travel around the circulator in the second direction to port **166** of waveguide power divider **165**.

In other embodiments, this two-state operation is achieved by the coordinated switching of the three circulators **120**, **130** and **140**. In that case, when triad switch **105** is in the first state, circulator **130** is switched "on" so that RF energy entering input port **131** flows through the circulator in the first direction and then out through port **114**. While triad switch **105** is in this first state, any reflected RF power received back into port **114** will enter into circulator **130** and travel around the circulator in the first direction to port **162** of waveguide power divider **165**. When triad switch **105** is in the second state, circulator **130** is switched "off." Any energy entering input port **131** (which should be negligible since circulator **120** is switched to circulator **140** in this first state) flows around the circulator in a second direction (opposite direction to the first direction) to port **133** and is directed to port **162** of waveguide power divider **165**.

Similarly, when triad switch **105** is in the second state, circulator **140** is switched "on", so that RF energy entering its input port **141** flows through the circulator in the second direction and then out through port **116**. While triad switch **105** is in this second state, any reflected RF power received back into port **116** will enter into circulator **140** and travel around the circulator in the second direction to port **166** of waveguide power divider **165**. When triad switch **105** is in the first state, circulator **140** is switched "off." Any energy entering input port **141** (which should be negligible since circulator **120** is switched to circulator **130** in this second state) flows around the circulator in the first direction (opposite direction to the second direction) to port **143** and is directed to port **166** of waveguide power divider **165**. The triad of switching circulators **120**, **130** and **140** are always switched in lock-step as a group. At any one instance in time, one, and only one, of the circulators **130**, **140** is switched to the "on" state. Similarly, at any one instance in time, circulator **120** is switched to only one of the circulators **130**, **140**, whichever is currently in the "on" state. In this way, reflected RF power back into the output ports **114** or **116** is always directed to either port **162** or port **166** of waveguide power divider **165**, and in turn distributed between waveguide load **152** and **154**.

With the embodiments provided by this disclosure, no one load element needs to be rated to handle the full power of a reflected wave. For example, in one implementation where reflected RF power is split evenly by waveguide power divider **165** between loads **152** and **154** (i.e. a 3 dB power divider), then each of the loads need only be rated for absorbing ½ of the maximum potential reflected RF power. In some embodiments, waveguide loads **152** and **154** are implemented, for example, using attenuating wave guides that comprises a tapered wedge design and/or absorbent material that substantially absorbs and spreads out the energy from reflected RF power along the length of the waveguide. It should also be appreciated that in other embodiment, waveguide power divider **165** may divide power between more than just two waveguide loads.

FIG. **2** is a block diagram shown generally at **200** where the waveguide power divider **165** for triad switch **105** is implemented using a quadrature coupler **210**. In this embodiment, with triad switch **105** in the first state, reflected RF power received back into output **114** will travel CW around circulator **130** from port **132** to **133** and enter waveguide power divider **165** at port **162** (indicated at **212**) and is split into two different waveguide paths (shown at **212-1** and **212-2**). The portion split to path **212-1** is delivered to and absorbed by waveguide load **152**. The portion split to path **212-2** is delivered to and absorbed by waveguide load **154**. When triad switch **105** is switched to the second state, reflected RF power received back into output **116** will travel CCW around circulator **140** from port **142** to **143** and enter waveguide power divider **165** at port **166** (indicated at **214**) and is split into different waveguide paths (shown at **214-1** and **214-2**). The portion split to path **214-1** is delivered to and absorbed by waveguide load **154**. The portion split to path **214-2** is delivered to and absorbed by waveguide load **152**. In the embodiment shown in FIG. **2**, quadrature coupler **210** is a 3 dB coupler, meaning that the power of an RF wave entering into either port **162** or **166** is evenly split between loads **152** and **154**. In other embodiments, quadrature coupler **210** may be alternately configured to unevenly split the power between the loads **152** and **154**. For example, in an implementation where load **152** is rated higher than load **154**, quadrature coupler **210** may be configured to distribute a larger portion of reflected RF power to load **152**. An uneven split such as described here may be applicable in cases where the reflected power received at one output may be greater than the reflected power received at the other output.

FIG. **3** is a block diagram shown generally at **300** where the waveguide power divider **165** for triad switch **105** is implemented using a Magic Tee waveguide power divider **310**. In this embodiment, with triad switch **105** in the first state, reflected RF power received back into output **114** will travel CW around circulator **130** from port **132** to **133** and enters waveguide power divider **165** at port **162** (indicated at **312**). When triad switch **105** is switched to the second state, reflected RF power received back into output **116** will travel CCW around circulator **140** from port **142** to **143** and enters waveguide power divider **165** at port **166** (indicated at **314**). A magic tee is a four-port hybrid splitter, realized in waveguide. In the embodiment shown in FIG. **3**, port **162** leads to a co-linear port and port **166** leads to a second co-linear port (though in other embodiments, these may be reversed). Ports **164** and **168** comprise, respectively an H-plane port and an E-plane port of the magic tee **310**. A reflected RF power signal (shown at **312**) incident on port **162** is equally split between ports **164** and **168** (which are coupled, respectively, to waveguide loads **152** and **154**), and isolated from port **166**. A reflected RF power signal (shown at **314**) incident on port **166** will also be equally split between ports **164** and **168**, and will be isolated from port **162**.

It should be appreciated that additional embodiments include multiple instances of triad switches such as switch **105** coupled together in various combinations to achieve different switching configurations. That is, the input port **112** of a triad switch may itself be coupled to a switched source of RF power. For example, input port **112** may be connected to the output port of an upstream circulator, or even to the output port of a prior upstream triad switch (which may, or may not, be a triad switch having a configuration such as shown with respect to triad switch **105**). In this way, a 1×4 switch configuration may be obtained, as an example, by coupling the respective input ports **112** of two instances of triad switch **105** to respective outputs of an upstream switching device which is coupled to the RF source.

FIG. **4** is a flow chart illustrating a method **400** of one embodiment of the present disclosure. In some embodiments, the method **400** may be implemented using any of the various embodiments and implementations discussed above with respect to triad switch **150**. In other embodiments, other variations on triad switch **150** may be utilized.

Method **400** begins at **410** with operating a ferrite circulator switch to direct RF power to either a first output port or a second output port, the ferrite circulator switch comprising at least three ferrite circulators arranged as a triad switch, wherein a first ferrite circulator is coupled to the first output port, a second circulator is coupled to the second output port. As mentioned above, a triad ferrite circulator switch comprises a triad of ferrite circulators, such as discussed above.

In one embodiment, the ferrite circulator switch further comprises a third circulator coupled to an input of the ferrite circulator switch. The third circulator directs RF power received at the input of the ferrite circulator switch to the first ferrite circulator when the switch is operating in the first state and directs RF power received at the input of the ferrite circulator switch to the second ferrite circulator when the switch is operating in the second state. In some embodiments, the first and second circulators (i.e., those connected to the first and second output of the triad ferrite circulator switch, are fixed to always direct RF power received from the third circulator to the outputs of the triad ferrite circulator switch. In other embodiments, the first, second and third circulators are each controlled in a lock-step manner such that the triad ferrite circulator switch is operated in either a first state or a second state as described above.

The method proceeds to **420** with using a waveguide power divider coupled between the first circulator and the second circulator, distributing reflected RF power received at the first output port or the second output port between a plurality of waveguide loads. When the ferrite circulator switch is switched to the first state and directs RF power to the first output, any reflected RF power received at the first output through the first circulator is directed to a first input port of the waveguide power divider. When the ferrite circulator switch is switched to the second state to direct RF power to the second output, any reflected RF power received at the second output through the second circulator of the triad switch is directed to the second input port of the waveguide power divider. In alternate embodiments, such as previously described above, the waveguide power divider can either evenly, or unevenly, distribute any reflected RF power received at the first or second ports of the waveguide power divider between the plurality of waveguide loads.

In some embodiments, the waveguide power divider in method **400** comprises a four port quadrature coupler having a first input port coupled to the first ferrite circulator and a second input port coupled to the second ferrite circulator, which may be a 3 dB coupler that evenly splits reflected power between the two waveguide loads. In other embodiments, the waveguide power divider comprises a magic tee waveguide power divider. In one such embodiment the magic tee waveguide power divider's H-plane port is coupled to the first waveguide load while the E-plane port is coupled to the second waveguide load.

For any of the embodiments described herein, additional embodiments may include more triad switches that further comprise supplemental isolators intervening between the input coupled circulator (such as circulator **120**) and the two output coupled circulators (such as circulators **130** and **140**). FIG. **5** illustrates one such embodiment where a triad switch **505** comprises the same elements as triad switch **105**, but further includes supplemental isolators **520** and **530**. In the embodiment shown in FIG. **5**, supplemental isolator **520** comprises a circulator **522** coupled to a first supplemental load **524** and is positioned between circulator **120** and circulator **130**. Supplemental isolator **530** comprises a circulator **532** coupled to a second supplemental load **534** and is positioned between circulator **120** and circulator **140**. With respect to supplemental isolator **520**, in operation, RF power received from circulator **120** is directed through circulator **522** to circulator **130** and then to output **114**. With respect to supplemental isolator **530**, in operation, RF power received from circulator **120** is directed through circulator **532** to circulator **140** and then to output **116**. As before, any reflected RF power received at either output **114** or **116** is directed to waveguide power divider **165** and waveguide loads **152** and **154**. In the case where the primary loads **152** and **154** are unable to completely absorb the reflected RF power, the balance of that reflected RF power exits waveguide power divider **165** and is directed through circulators **130** and **140** to one or both of supplemental isolators **520** and **530**. Reflected power received at supplemental isolators **520** and **530** is then directed (by circulators **522** and **532**) to the supplemental waveguide loads **524** and **534** which will further attenuate the reflected RF power, thus providing additional isolation between output ports **114** and **116**. In still other embodiments, additional supplemental isolators, such as **520** and **530**, may similarly be coupled between the input coupled circulator **120** and the two output coupled circulators **130** and **140** to provide still further isolation.

Example Embodiments

Example 1 includes a high power circulator switch, the switch comprising: at least three ferrite circulators, the at least three ferrite circulators arranged as a triad switch, wherein a first circulator is coupled to a first output of the triad switch, a second circulator is coupled to a second output of the triad switch, and a third circulator coupled to an input of the triad switch; a waveguide power divider comprising a first port coupled to the first circulator and a second port coupled to the second circulator; at least two waveguide loads including a first waveguide load and a second waveguide load, wherein the first waveguide load is coupled to a third port of the waveguide power divider and the second waveguide load is coupled to a fourth port of the waveguide power divider; wherein the waveguide power divider distributes any RF power received at the first port of the waveguide power divider between the at least two waveguide loads; and wherein the waveguide power divider distributes any RF power received at the second port of the waveguide power divider between the at least two waveguide loads.

Example 2 includes the switch of example 1, wherein when the triad switch is switched to a first state, RF power received at the input is directed through the third circulator and the first circulator to the first output, and any reflected RF power received at the first output is directed by the first circulator to the first port of the waveguide power divider; and wherein when the triad switch is switched to a second state, RF power received at the input is directed through the third circulator and the second circulator to the second output, and any reflected RF power received at the second output is directed by the second circulator to the second port of the waveguide power divider.

Example 3 includes the switch of any of examples 1-2, wherein the first circulator and the second circulator remain in a fixed switching state when a switching state of the third circulator is switched.

Example 4 includes the switch of any of examples 1-3, wherein the first circulator and the second circulator are switched between states in lock-step with switching of the third circulator.

Example 5 includes the switch of any of examples 1-4, wherein the waveguide power divider evenly distributes any reflected RF power received at the first or second ports of the waveguide power divider between the at least two waveguide loads.

Example 6 includes the switch of any of examples 1-5, wherein the waveguide power divider unevenly distributes any reflected RF power received at the first or second ports of the waveguide power divider between the at least two waveguide loads.

Example 7 includes the switch of any of examples 1-6, wherein the waveguide power divider comprises a four port quadrature coupler having a first input port coupled to the first circulator and a second input port coupled to the second circulator.

Example 8 includes the switch of any of examples 1-7, wherein the waveguide power divider comprises a magic tee waveguide power divider.

Example 9 includes the switch of example 8, wherein the magic tee waveguide power divider comprises an H-plane port coupled to the first waveguide load and an E-plane port coupled to the second waveguide load.

Example 10 includes a method for switching RF power using a high power circulator switch, the method comprising: operating a ferrite circulator switch to direct RF power to either a first output port or a second output port, the ferrite circulator switch comprising at least three ferrite circulators arranged as a triad switch, wherein a first circulator is coupled to the first output port, a second circulator is coupled to the second output port; using a waveguide power divider coupled between the first circulator and the second circulator, distributing reflected RF power received at the first output port or the second output port between a plurality of waveguide loads.

Example 11 includes the method of examples 10, further comprising: when the ferrite circulator switch is switched to a first state to direct RF power to the first output, directing any reflected RF power received at the first output through the first circulator to a first input port of the waveguide power divider; when the ferrite circulator switch is switched to a second state to direct RF power to the second output, directing any reflected RF power received at the second output through the second circulator of the triad switch to the second input port of the waveguide power divider.

Example 12 includes the method of any of examples 10-11, wherein the waveguide power divider evenly distributes any reflected RF power received at the first or second ports of the waveguide power divider between the plurality of waveguide loads.

Example 13 includes the method of any of examples 10-12, wherein the waveguide power divider unevenly distributes any reflected RF power received at the first or second ports of the waveguide power divider between the plurality of waveguide loads.

Example 14 includes the method of any of examples 10-13, wherein the ferrite circulator switch further comprises a third circulator coupled to an input of the ferrite circulator switch, wherein the method further comprises: the third circulator directing RF power received at the input of the ferrite circulator switch to the first circulator when the switch is operating in the first state; and the third circulator directing RF power received at the input of the ferrite circulator switch to the second circulator when the switch is operating in the second state.

Example 15 includes the method of any of example 10-14, wherein the first circulator and the second circulator remain in a fixed switching state when a switching state of the third circulator is switched.

Example 16 includes the method of any of examples 10-14, wherein the first circulator and the second circulator are switched between states in lock-step with switching of the third circulator.

Example 17 includes the method of any of examples 10-16, wherein the waveguide power divider comprises a four port quadrature coupler having a first input port coupled to the first circulator and a second input port coupled to the second circulator.

Example 18 includes the method of any of examples 10-17, wherein the waveguide power divider comprises a magic tee waveguide power divider.

Example 19 includes the method of any example 18, wherein the magic tee waveguide power divider comprises an H-plane port coupled to a first waveguide load and an E-plane port coupled to a second waveguide load.

Example 20 includes the switch of any of examples 1-9 or method of any of examples 10-19, further comprising at least a first supplemental isolator intervening between the first circulator and the third circulator, and at least a second supplemental isolator intervening between the second circulator and the third circulator.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement, which is calculated to achieve the same purpose, may be substituted for the specific embodiment shown. This application is intended to cover any adaptations or variations of the present disclosure. Therefore, it is manifestly intended that this invention be limited only by the claims and the equivalents thereof.

What is claimed is:

1. A high power circulator switch, the switch comprising:

at least three ferrite circulators, the at least three ferrite circulators arranged as a triad switch, wherein a first circulator is coupled to a first output of the triad switch, a second circulator is coupled to a second output of the triad switch, and a third circulator coupled to an input of the triad switch;

a waveguide power divider comprising a first port coupled to the first circulator and a second port coupled to the second circulator;

at least two waveguide loads including a first waveguide load and a second waveguide load, wherein the first waveguide load is coupled to a third port of the waveguide power divider and the second waveguide load is coupled to a fourth port of the waveguide power divider;

wherein the waveguide power divider distributes any RF power received at the first port of the waveguide power divider between the at least two waveguide loads; and

wherein the waveguide power divider distributes any RF power received at the second port of the waveguide power divider between the at least two waveguide loads.

2. The switch of claim **1**, wherein the waveguide power divider comprises a four port quadrature coupler having a first input port coupled to the first circulator and a second input port coupled to the second circulator.

3. The switch of claim **1**, further comprising at least a first supplemental isolator intervening between the first circulator and the third circulator, and at least a second supplemental isolator intervening between the second circulator and the third circulator.

4. The switch of claim **1**, wherein the waveguide power divider comprises a magic tee waveguide power divider.

5. The switch of claim **4**, wherein the magic tee waveguide power divider comprises an H-plane port coupled to the first waveguide load and an E-plane port coupled to the second waveguide load.

6. The switch of claim **1**, wherein when the triad switch is switched to a first state, RF power received at the input is directed through the third circulator and the first circulator to the first output, and any reflected RF power received at the first output is directed by the first circulator to the first port of the waveguide power divider; and

wherein when the triad switch is switched to a second state, RF power received at the input is directed through the third circulator and the second circulator to the second output, and any reflected RF power received at the second output is directed by the second circulator to the second port of the waveguide power divider.

7. The switch of claim **6**, wherein the first circulator and the second circulator remain in a fixed switching state when a switching state of the third circulator is switched.

8. The switch of claim **6**, wherein the first circulator and the second circulator are switched between states in lock-step with switching of the third circulator.

9. The switch of claim **6**, wherein the waveguide power divider evenly distributes any reflected RF power received at the first or second ports of the waveguide power divider between the at least two waveguide loads.

10. The switch of claim **6**, wherein the waveguide power divider unevenly distributes any reflected RF power received at the first or second ports of the waveguide power divider between the at least two waveguide loads.

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